APPLICATION FOR UNITED STATES PATENT

FOR

PIVOTABLE SLURRY ARM

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PIVOTABLE SLURRY ARM

Technical Field

Embodiments of the present invention relate to apparatuses and methods for chemical mechanical planarization and, more particularly, to the dispensing of polishing slurry for a substrate being polished.

Background

Chemical mechanical planarization (CMP) is a popular method of planarizing the surface of a semiconductor substrate. CMP combines chemical reaction and mechanical abrasion to remove raised features on the surface of the semiconductor substrate. Planarity of the surface is a critical dimension for integrated circuit fabrication.

Commonly, the apparatus used to planarize the substrate includes a polishing pad mounted on a flat rotating platen. One type of polishing pad is comprised of polyurethane material. A polyurethane pad is used as a polishing media because it is compliant and serves as a transport of polishing chemistry to the substrate during a polishing process. A slurry containing abrasive particles and/or chemical etchants is commonly used to abrade and/or etch the surface of the substrate.

The substrate is held in a carrier and is presented to the polishing pad from above. The semiconductor substrate contacts the polishing pad at a predetermined pressure, which partially determines the rate of material removal. The contact pressure between the substrate and the polishing pad is provided by a combination of mechanisms, including mechanical and gas pressure/vacuum, that moves the carrier and gas pressure applied to the back-side of the substrate.

A slurry of abrasives and/or chemical etchants is delivered to the surface of the polishing pad by a slurry arm. The slurry arm is fixedly positioned over the polishing pad and has one or more nozzles that expel the slurry over the polishing pad. The nozzles are positioned along the

slurry arm in fixed locations and deposit the slurry to predefined locations on the polishing pad. The resulting distribution of slurry about the surface of the polishing pad is dependant on, among other things, the number of nozzles, their placement and the fate of flow of the slurry.

The rotation of the polishing pad and the movement of the substrate about the polishing pad spreads the slurry over the polishing pad surface and between the substrate and the polishing pad.

Obtaining uniformity over the substrate surface is a major challenge in the CMP process. One reason for this is that the distribution of the slurry is less than ideal as the substrate traverses about the rotating polishing pad from center to edge. At any given time, the smaller diameter substrate surface will see a variation in slurry film thickness across the contact surface with the larger diameter polishing pad. Minimization of this slurry variation is attempted in a number of ways with limited success. One method is to increase the number of nozzles on the slurry arm to cover the linear radial distribution of slurry from the center to the edge of the polishing pad. This reduces the slurry variation over the portion of the polishing pad immediately below the slurry arm, but does not eliminate it away from where the slurry is deposited. This method becomes impractical especially considering that the trend in the art is for increasing the substrate diameter which will require and increase in polishing pad diameter and exasperate the slurry differential for a given number of nozzles and/or flow rate.

The current approaches in the attempt to reduce slurry film thickness differential over the polishing pad surface have their limitations due to the nozzle distributions and the quantity of slurry necessary to feed the nozzles. These approaches require the greatest amount of slurry solution to be used to continuously feed the plurality of nozzles over the entire radial deposition location resulting in a relatively great amount of slurry solution to go unused by the substrate at any given time and location on the polishing pad. The over distribution of slurry solution results in a greater amount of potentially hazardous material that must be supplied to the polishing pad and used in

the CMP process as well as a greater amount of potentially hazardous material requiring disposal.

As portions of the substrate are removed by the polishing pad, a combination of slurry and debris tends to clog or embed in the surface of the polishing pad. Methods of cleaning the polishing pad surface incorporates the use of a conditioning disc, in place of the substrate, having an abrasive surface that engages the surface of the polishing pad. The conditioning pad lifts and removes the clogging materials so that they can be rinsed away. Conditioning pads are commonly made of a higher durometer material as the polishing pad such that the conditioning pad can abrasively clean and replanarize the polishing pad.

As with polishing the substrate, the process of conditioning the polishing pad incorporates the use of a fluid solution, in this case, a cleaning solution. The limitations involved with providing a uniform slurry distribution over the substrate are also found in the process of conditioning the pad.

Thus, further improvements are needed for slurry delivery.

Brief Description of Drawings

Figure 1 is a perspective view of a CMP apparatus comprising a slurry arm, a polishing pad platen and a substrate carrier, in accordance with an embodiment of the present invention;

Figure 2 is a top view of the slurry arm, in accordance with an embodiment of the present invention;

Figures 3 and 4 are side and front views of the slurry arm, in accordance with an embodiment of the present invention;

Figures 5 and 6 are side and front views of the slurry arm, in accordance with other embodiments of the present invention; and

Figure 7 is a flow chart of the operational flow for using the CMP apparatus of Fig. 1, in accordance with an embodiment of the present invention.

Detailed Description of Embodiments

In the following detailed description, reference is made to the accompanying drawings which form a part hereof wherein like numerals designate like parts throughout, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present invention. Therefore, the following detailed description is not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims and their equivalents.

Embodiments of methods and apparatus in accordance with the present invention provide CMP methods and apparatuses that provide a rotatable and/or pivotable slurry arm with control over slurry delivery position, slurry flow rate, and other aspects. In particular, the position of the slurry arm is controllable to facilitate provision of a substantially uniform slurry film over a particular zone of a polishing pad for planarization of a substrate. The slurry arm control is in electrical communication with a substrate holder holding the substrate, to provide for a coordinated sequence wherein the deposition of the slurry is in anticipation of the position of the substrate at any given period of time.

Figure 1 is a perspective view of a CMP apparatus comprising a slurry arm 10, a polishing pad platen 20 and a substrate carrier 30, in accordance with an embodiment of the present invention. The polishing pad platen 20 provides a planar turntable to support a polishing pad 22, commonly found in the art. The substrate carrier 30 supports a substrate 34 on a planar turntable in opposing relationship with the polishing pad 22. The substrate carrier 30 is adapted to position the substrate 34 about and in urging engagement with the polishing pad 22 to effect a polishing pattern on the surface of the polishing pad 22. The substrate holder 30 and the polishing pad platen 20 may be adapted to rotate at a constant or variable velocity depending on the need at a particular time.

The slurry arm 10 comprises a fore arm 15 coupled at a proximal end 17 to a drive shaft 19 adapted for rotation about a shaft axis 14 in either a clockwise or counterclockwise direction 11. The fore arm 15 further comprises a nozzle 12 at a distal end 16 opposite the proximal end 17.

The slurry arm 10, when in operation, extends above and substantially parallel with the polishing pad 22. The slurry arm 10 is adapted to pivot about axis 21 adjacent the polishing pad platen 20 with a rotation velocity and position 11. The slurry arm 10 is adapted such that the nozzle 12 is positioned at a predetermined location 18 over the polishing pad 22.

Figure 2 is a top view of the slurry arm 10 in accordance with the embodiment of Figure 1. The extent of positioning of the fore arm 15, and therefore the nozzle 12, is from a nozzle position of at least from perimeter to perimeter of the polishing pad platen 20 about a swing angle over the polishing pad 22 along the rotation axis 14 of the drive shaft 19. The length of the fore arm 15 is adapted to overhang at least a working portion of the polishing pad 22 with a predetermined length beyond the perimeter of the polishing pad 22 to effect a pivoting motion for a predetermined arc-shaped slurry deposition path 26 on the polishing pad 22. The working portion of the polishing pad is defined at that part of the surface of the polishing pad that comes into contact with the substrate 34 during the CMP process.

The rotation velocity (Vp) and direction of the slurry arm 10 is variable and may be selected for a particular purpose. In one embodiment of the method of the present invention, the Vp of the slurry arm 10 is controlled to coordinate with the radial positioning of the substrate 34 by the substrate holder 30 about the polishing pad 22. The nozzle 12 is positioned above the polishing pad 22 such that, considering polishing pad platen 20 speed of rotation, slurry deposition is provided to be on a path 27 for coincident engagement with the substrate 34.

Figures 3 and 4 are side and front views of embodiments of pivoting slurry arms, in accordance with an embodiment of the present invention.

The slurry arm 10 comprises a fore arm 15 coupled at a proximal end 17 to a drive shaft 19 adapted for rotation about a shaft axis 14 in either a clockwise or counterclockwise direction 11. The fore arm 15 further comprises a nozzle 12 at a distal end 16 opposite the proximal end 17. The embodiment of Figures 3-4 illustrates the nozzle 12 comprising multiple slurry ports 13. The multiple slurry ports 13 are aimed such that the slurry will be deposited on the polishing pad 22 at a predetermined target area 18.

In one embodiment, the multiple slurry ports 13 provide the same slurry solution to the polishing pad 22 at the predetermined target area 18. The multiple slurry ports 13 are provided for a particular purpose, such as, but not limited to, providing a concentrated slurry film at a precise target area 18 and providing an enlarged target area 18 than can be provided by a single slurry port 13.

In other embodiments of the present invention, one or more slurry ports 13 provide different slurry solutions, such as, but not limited to, an abrasive slurry and a chemical etchant. The controller is adapted to control the flow of the different slurry streams in accordance with selected polishing criteria. For example, but not limited thereto, a chemical etchant from one slurry port 13 and an abrasive slurry from another slurry port 13 is controlled to provide a predetermined concentration of the two slurry solutions by controlling the flow rate of the individual slurry ports 13. A higher abrasive concentration may be suitable for early stage polishing, wherein a higher concentration of chemical etchant is suitable for an end stage of polishing.

Figures 5 and 6 are side and front views, respectively, of other embodiments of the slurry arm, including its nozzles, in accordance with other embodiments of the present invention. Figure 5 illustrates a nozzle 12 comprising a single slurry port 13. Figure 6 illustrates a nozzle 12 comprising two slurry ports 13.

In an embodiment of the method of the invention, the slurry flow rate is continuously varied with nozzle 12 positioning across the polishing pad 22 to compensate for the velocity differential with respect to radial positioning of

the polishing pad 22, from the platen rotation axis 29 to the platen perimeter 23.

Referring to Fig. 1 again, in various embodiments, the operation of slurry arm 10 is controlled by control system 50. In various embodiments, control system 50 controls the operation of slurry arm 10 based on the inputs for the earlier described parameters governing the operation of slurry arm 10. In various embodiments, control system 50 is in communication with the substrate holder to facilitate coordinated engagement with one other. As will be further described below, in various embodiments, control system 50 may also control operation of slurry arm 10 based on feedback, including are not limited to feedback from an in-situ process/substrate surface metrology system (not shown).

Figure 7 is a flow chart of an operational flow for controlling a CMP apparatus having the programmable slurry arm 10 in accordance with an embodiment of the present invention. The operational flow starts with the selection of one or more variable control parameters 70. For the embodiment, the selectable variable control parameters include, but are not limited to, slurry arm position, rotation velocity, slurry flow rate, slurry concentration/dispensing control, nozzle position, platen speed, and/or substrate position.

Upon selection of the variable control parameters; their values are adjusted 72, based at least in part on the anticipated locations of the substrate at different points in time.

Upon adjustment, the CMP apparatus is operated, resulting in programmable slurry arm 10 providing a slurry film of certain thickness 74 at the anticipated substrate locations along a flow path, for e.g. the planarization of the substrate.

At 76, feedback from the CMP apparatus and/or an in-situ process/substrate surface metrology system (not shown) may be obtained.

The feedback may include, but are not limited to, the resulting planarization of a substrate, the slurry film thickness, the provisioning locations, and so forth.

Based on the feedback, the process may return to 74, where the selected variable control parameters may be re-adjusted for the desired operation. From 74, the process continues onto 76 as earlier described.

Alternatively, based on the feedback, the process may return to 72, where one or more of the previously selected variable control parameters may be de-selected, and/or one or more other variable control parameters may be selected. From 72, the process continues onto 74 as earlier described.

The embodiments of apparatus and methods in accordance with the present invention provide the possibility of processing larger semiconductor substrates more reliably, consistently and uniformly during the planarization process as well as likely more efficient utilization of slurry solution with reduced amount of waste.

It is understood that embodiments of the present invention may also be applied to processes and apparatuses for the conditioning of the polishing pad.

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a wide variety of alternate and/or equivalent implementations calculated to achieve the same purposes may be substituted for the specific embodiments shown and described without departing from the scope of the present invention. Those with skill in the art will readily appreciate that the present invention may be implemented in a very wide variety of embodiments. This application is intended to cover any adaptations or variations of the embodiments discussed herein. Therefore, it is manifestly intended that this invention be limited only by the claims and the equivalents thereof.